Application

For

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Title:

Method and System for Image Chroma Suppression

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Method and System for Image Chroma Suppression

FIELD OF THE INVENTION:

The invention relates to image sensor chroma suppression, particularly to chroma suppression that relies on spatial frequency information without needing to increase the existing image sensor line buffer size.

BACKGROUND:

In demosaicking Bayer pattern images captured by an image sensor, "false color" can be induced at or near places such as an edge, a checkered pattern or a stripe pattern. As such, a need exists for reducing the false color phenomena at or near edges, checkered patterns or stripe patterns.

BRIEF DESCRIPTION OF THE FIGURES:

The accompanying drawings which are incorporated in and form a part of this specification, illustrate embodiments of the invention and together with the description, serve to explain the principles of the invention:

Figure 1 shows an image sensor chip for chroma suppression in accordance with one embodiment of the invention.

Figure 2 shows some of the units involved for performing chroma suppression in accordance with one embodiment of the invention.

Figure 3 shows a Bayer pattern having a green current processing pixel in accordance with one embodiment of the invention.

Figure 4 shows another Bayer pattern having a non-green current processing pixel in accordance with one embodiment of the invention.

Figure 5 is flow chart that outlines steps for performing chroma suppression in accordance with one embodiment of the invention.

DETAILED DESCRIPTION:

Reference is made in detail to embodiments of the invention. While the invention is described in conjunction with the embodiments, the invention is not intended to be limited by these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims. Furthermore, in the following detailed description of the invention, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, as is obvious to one ordinarily skilled in the art, the invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail so that aspects of the invention will not be obscured.

Figure 1 shows an image sensor chip 100 for chroma suppression in accordance with one embodiment of the invention.

Image sensor chip 100 comprises an image sensor array 110 and an image processing component 150. Image sensor array 110 is adapted for capturing and digitizing images to be processed by image processing component 150. Image sensor chip 100 is typically used within an image-capturing device that could be, but is not limited to, a digital camcorder, a digital still camera, a videophone, a video conferencing equipment, a PC camera, a cell phone, or a security monitor.

Image sensor array 110 comprises an image sensor 115, and an analog-to-digital converter (ADC) 120. Image processing component 150 comprises a color processing component 155, a compression engine 160 and a transceiver 165.

Images are captured by sensor 115, then digitized by ADC 120 into pixel values to be transmitted to image processing component 150. Then, the pixel values are color processed by color processing component 155. Color processing component 155 typically performs digital image processing that could include, but is not limited to, auto exposure control, color interpolation, edge detection, chroma suppression, auto white balancing, color correction and image sharpening. In turn, the color processed pixel values undergo compression performed by compression engine 160. The compressed image data is then transmitted out of image sensor chip by transceiver 165.

Referring now to Figure 2 in view of Figure 1, Figure 2 shows units included in color processing component 155 in accordance with one embodiment of the invention. These units comprise a color interpolation unit 210, an edge detection unit 220, a white balance gain unit 230, a chroma suppression unit 240, a color correction unit 250 and a line buffer for color interpolation unit 210.

Specifically, edge detection unit 220 and chroma suppression unit 240 are involved for chroma suppression in accordance with the present embodiment. Furthermore, also shown coupled to both color interpolation unit 210 and edge detection unit is line buffer 290 that is adapted for storing pixel values to be used for performing

interpolation of pixel values for a current processing pixel. Line buffer 290 can also to be used for chroma suppression in the present embodiment. As such, in the present embodiment, performing chroma suppression does not require extra line buffers in addition to that of color interpolation unit 210.

Chroma suppression is adapted to reduce false color that occurs at or near an edge, a checkered pattern, or a stripe pattern in an image. As such, before chroma suppression is performed, these problematic locations needing chroma suppression are first identified. In turn, chroma suppression is performed on these problematic locations.

Specifically, in the present embodiment, edge detection unit 220 is adapted to indicate whether a current processing pixel is at or near an edge, a checkered pattern, or a stripe pattern. A pixel at or near these problematic image patterns typically has high spatial frequency. As such, edge detection unit 220 is adapted to determine whether the current processing pixel is in a high spatial frequency region or not in order to determine whether the current processing pixel is at or near an edge, a checkered, pattern, or a stripe pattern. If the current processing pixel is in a high spatial frequency region, then chroma suppression unit 240 is triggered to perform chroma suppression at the current processing pixel by reducing the intensity of the current processing pixel. The degree of intensity reduction can be flexibly adjusted.

More specifically, edge detection unit 220 is adapted to detect the presence of an edge, a checkered pattern, or a strip pattern without having to use pixel values other than some of pixel values already available in line buffer 290, wherein pixels values in line buffer 290 are originally intended for performing color interpolation by color interpolation unit 210. In so doing, no extra line buffer besides line buffer 290 is required by edge detection unit 220 in locating problematic locations in an image. As such, in the present embodiment, chroma suppression can be performed without extra line buffer besides line buffer 290.

Moreover, edge detection unit 220 does not require any non-green pixel values in determining spatial frequency of the current processing pixel. Whether the current processing pixel is a green pixel or not, edge detection unit 220 can use pixel values of green pixels that surround the current processing pixel.

In view of Figures 1-2, Figure 3 shows a Bayer pattern 300 having a green current processing pixel M22 that might undergo chroma suppression in accordance with one embodiment of the invention.

Bayer pattern 300 comprises 16 pixels (M00, M01, ... and M33) as shown, wherein green pixel M22 is the current processing pixel. These 16 pixels are already available for access from line buffer 290 because they are also used by color interpolation unit 210 for performing color interpolation.

Specifically, pixels M00-M33 are arranged as a 4 by 4 Bayer pattern having green pixel M22 as current processing pixel. As such, besides current processing pixel M22 being a green pixel, its surrounding pixels M00, M02, M11, M13, M20, M22, M31 and M33 are also green pixels.

Continuing with Figure 3, given a current processing pixel like green pixel M22, edge detection unit 220 uses the surrounding green pixels (i.e., M00, M02, M11, M13, M20, M31 and M33) of green pixel M22 to determine whether current processing pixel M22 is in a high frequency region or not. If current processing green pixel M22 is found to be in a high frequency region, then chroma suppression is performed on current processing pixel M22 by chroma suppression unit 240, thereby reducing undesirable false color.

Within Bayer pattern 300, only the values of green pixels surrounding current processing pixel M22 need to be used by edge detection unit 220 in determining whether chroma suppression is to be performed or not. As these green pixel values are already accessible from line buffer 290, edge detection unit 220 can share the same line buffer 290 with color interpolation unit 210.

As understood herein, the invention need not be limited to using only green pixels surround green pixel M22. For example, in another embodiment, values of non-green pixels (stored in line buffer 290) surrounding green pixel M22 are used.

Also, as understood herein, the Bayer pattern used need not be limited to a 4 X 4 block. For example, in another embodiment, a 5 X 5 block is used.

In view of Figures 1-2, Figure 4 shows another Bayer pattern 400 having a non-green pixel M22 as a current processing pixel that might undergo chroma suppression in accordance with one embodiment of the invention.

Bayer pattern 400 comprises 16 pixels (M00, M01, ... and M33), wherein M22 is a current processing pixel. These 16 pixels are already available for access from line buffer 290 because they are also used by color interpolation unit 210 for performing color interpolation.

Specifically, pixels M00-M33 are arranged as a 4 by 4 Bayer pattern having a non-green (i.e., blue or red) pixel as current processing pixel M22. As such, because current processing pixel M22 is a non-green pixel, its surrounding pixels M10, M30, M01, M21, M12, M32, M03 and M23 are green pixels.

Continuing with Figure 4, given a current processing pixel like non-green pixel M22, edge detection module 220 uses the surrounding green pixels (i.e., M10, M30, M01, M21, M12, M32, M03 and M23) of non-green current processing pixel M22 to determine whether current processing pixel M22 is in a high frequency region or not. If current processing non-green pixel M22 is found to be in a high frequency region, then chroma suppression is performed on current processing pixel M22 by chroma suppression module 240, thereby reducing undesirable false color.

Within Bayer pattern 400, only green pixels surrounding non-green current processing pixel M22 need to be used by edge detection unit 220 in determining whether chroma suppression is to be performed or not. As these green pixel values are already accessible from line buffer 290, edge detection unit 220 can share the same line buffer 290 with color interpolation unit 210.

As understood herein, the invention need not be limited to using only green pixels surround green pixel M22. For example, in another embodiment, values of non-green pixels (stored in line buffer 290) surrounding non-green pixel M22 are used.

Also, as understood herein, the Bayer pattern used need not be limited to a 4 X 4 block. For example, in another embodiment, a 5 X 5 block is used.

In view of Figures 3-4, Figure 5 shows a flow chart 500 outlining steps for performing chroma suppression in accordance with one embodiment of the invention.

In query step 505, a check is made to determine if a current processing pixel M22 within a 4x4 Bayer pattern (as shown in Figures 3 and 4) is a green pixel or non-green pixel. If M22 is a green pixel, then Bayer pattern to be examined is Bayer pattern 300 shown in Figure 3. In turn, step 510 is performed next. Otherwise, if M22 is a

non-green pixel, then Bayer pattern to be examined is Bayer pattern 400 shown in Figure 4. In turn, step 520 is performed next.

In step 510 (for M22 being a green pixel), high pass filtering is performed on green pixels surrounding the current processing pixel M22.

Specifically, the first order pixel value sums are calculated before the spatial frequency of green pixel M22 is calculated. These first order pixel value sums are calculated with the green pixel values (i.e., M00, M20, M11, M31, M02, M22, M13, M33) within the Bayer pattern (see Bayer pattern 300 of Figure 3).

First, a first plurality of 4 first order pixel value sums V[0] to V[3] are calculated, wherein for i = 0 to 3 an i-th pixel value sum V[i] characterizes the pixel value sum for a pair of buffered green pixel values associated respectively with a pair of green pixels lying on the i-th vertical column of the Bayer pattern region. V[i] can be considered as an "average" of pixel values for the two green pixels lying in the i-th column of the Bayer pattern region.

Second, a second plurality of 4 first order pixel value sums H[0] to H[3] are calculated, wherein for j = 0 to 3 an j-th pixel value sum H[j] characterizes the pixel value sum for a pair of buffered green pixel values associated respectively with a pair of green pixels lying in the j-th horizontal column of said Bayer pattern region. H[j] can be considered as an "average" of pixel values for the two green pixels lying in the j-th column of the Bayer pattern region.

Specifically, before the spatial frequency of green pixel M22 is calculated, the first order pixel value sums are calculated as follow:

V[0] = (M00+M20) as an "average" of values of M00 and M20;

V[1] = (M11 + M31) as an "average" of values of M11 and M31;

V[2] = (M02 +M22) as an "average" of values of M02 and M22;

V[3] = (M13 +M33) as an "average" of values of M13 and M33;

H[0] = (M00 + M02) as an "average" of values of M00 and M02;

H[1] = (M11 + M13) as an "average" of values of M11 and M13;

H[2] = (M20 + M22) as an "average" of values of M20 and M22; and

H[3] = (M31 + M33) as an "average" of values of M31 and M33.

In turn, step 530 is performed next.

In step 520 (for M22 being a non-green pixel), high pass filtering is performed on green pixels surrounding the current processing pixel M22.

Specifically, before the spatial frequency of non-green pixel M22 is calculated, the first order pixel value sums are calculated before the spatial frequency of non-green pixel M22 is calculated. These first order pixel value sums are calculated with the green pixels (i.e., M10, M30, M01, M21, M12, M32, M03, M23, M01, M03, M10, M12, M21, M23, M30 and M32) within the Bayer pattern (see Bayer pattern 400 of Figure 4).

First, a first plurality of 4 first order pixel value sums V[0] to V[3] are calculated, wherein for i = 0 to 3 an i-th pixel value sum V[i] characterizes the pixel value sum for a pair of buffered green pixel values associated respectively with a pair of green pixels lying on the i-th vertical column of said Bayer pattern region. V[i] can be considered as an "average" of pixel values for the two green pixels lying in the i-th column of the Bayer pattern region.

Second, a second plurality of 4 first order pixel value sums H[0] to H[3] are calculated, wherein for j = 0 to 3 an j-th pixel value sum H[j] characterizes the pixel value sum for a pair of buffered green pixel values associated respectively with a pair of green pixels lying in the j-th horizontal column of said Bayer pattern region. H[j] can be considered as an "average" of pixel values for the two green pixels lying in the j-th column of the Bayer pattern region.

Specifically, before the spatial frequency of green pixel M22 is calculated, the first order pixel value sums are calculated as follow:

V[0] = (M10 + M30) as an "average" of values of M10 and M30;

V[1] = (M01 + M21) as an "average" of values of M01 and M21;

V[2] = (M12 + M32) as an "average" of values of M12 and M32;

V[3] = (M03 + M23) as an "average" of values of M03 and M23;

H[0] = (M01 + M03) as an "average" of values of M01 and M03;

H[1] = (M10 + M12) as an "average" of values of M10 and M12;

H[2] = (M21 + M23) as an "average" of values of M21 and M23; and

H[3] = (M30 + M32) as an "average" of values of M30 and M32.

In turn, step 530 is performed next.

In step 530, noise reduction is performed.

Specifically, the second order pixel value differences are calculated from the first order pixel value differences calculated either in step 510 (for M22 being a green pixel) or in step 520 (for M22 being a non-green pixel).

More specifically, the second order pixel value sums are calculated as follow:

V0avg = (V[0] + V[2]) as an "average" of V[0] and V[2];

V1avg = (V[1] + V[3]) as an "average" of V[1] and V[3];

H0avg = (H[0] + H[2]) as an "average" of H[0] and H[2]; and

H1avg = (H[1] + H[3]) as an "average" of H[1] and H[3].

In step 540, preliminary values of spatial frequency for the current processing pixel are calculated. These preliminary values are the third order pixel value differences as calculated from the second pixel value sums calculated in step 530.

Specifically, the third order pixel value differences are calculated as follow:

Vmax = | V0avg – V1avg | as a preliminary value of spatial frequency; and

Hmax = | H0avg – H1avg | as a preliminary value of spatial frequency.

Vmax and Hmax will be used in determining whether or not current processing pixel M22 is near an edge, a checkered pattern, or a stripe pattern, and thus in a high spatial frequency region.

In step 550, a spatial frequency value SF[1] is assigned to current processing pixel M22. Specifically, SF[1] is defined as:

SF[1] = MAX (Vmax, Hmax).

In step 560, noise reduction is performed on current processing pixel M22 by fine-tuning spatial frequency SF[1] obtained in step 550. This noise reduction step adjusts the spatial frequency as follow:

SF[2] = MIN (255, MAX(0, (SF - T))).

As understood herein, the quantity SF[2] indicates if current processing pixel M22 is in a high spatial frequency region or not. Specifically, large value of SF[2] indicates higher spatial frequency for current processing pixel M22. T is a parameter for tolerating low spatial deviation, wherein the range of T is from 0 to 255. Again, whether step 530 is performed following step 510 or step 520, only pixel values of green pixels (already available from the line buffer used for interpolation) need to be used in determining the degree of spatial frequency intensity for current processing pixel M22. As such, exiting line buffer space of the color interpolation unit of an image sensor can be

used. In turn, in evaluating whether or not M22 is in a high spatial frequency region in need of chroma suppression, the same line buffers in the color interpolation unit of an image sensor can be used for the purpose of chroma suppression.

As understood herein, the invention is not limited to the formula listed in step 505-550 of the present embodiment. The above listed formula and their associated numerical values are for demonstrate purpose only. For example, in another embodiment of the invention, other numerical values can be used in place of the numerical values listed in steps 505-570.

In query step 570, a test is made to check if SF[2] indicates current processing pixel M22 as being in a high spatial frequency region. If yes, then step 580 is performed. Otherwise, step 580 is bypassed.

Specifically, SF[2] is compared to a threshold value T. If SF[2] > T, then SF[2] indicates that M22 is in a high spatial frequency region.

In step 580, chroma suppression is performed on current processing pixel M22 in accordance with the strength of SF[2] as calculated in step 560. Specifically, chroma suppression is performed by reducing the chromatic saturation of current processing pixel M22.

Assuming the spatial frequency of M22 is greater than the threshold (i.e., SF[2] > T), an attenuation factor F for chroma suppression is given as F = MIN (255, MAX(0,255 – SF[2] * W)), wherein W is a parameter that quantifies the strength of chroma suppression.

Then, transformation from RGB space to YUV space is performed as follow:

$Y = (77*R + 150*G + 29*B)/256$;

$U = (-44*R - 87G + 131*B)/256$; and

$V = (131*R - 110*G - 21*B)/256$.

As understood herein, Y is the luminance of the current processing pixel. U and V are the chroma components of current processing pixel M22, wherein U and V are used to determine the original chromatic saturation of current processing pixel M22. Moreover, because chroma suppression is understood to be the reduction of the original chromatic saturation of the current processing pixel, chroma suppression is performed by reducing U and V respectively into U' and V', wherein U' and V' are used to determine a new chromatic saturation for current processing pixel M22. In so doing, the new chromatic saturation determined from U' and V' is reduced relative to the original chromatic saturation, thereby achieving chromatic suppression for current processing pixel M22.

Continuing with step 580, the attenuation factor F is rescaled as F/256 (i.e., a number between 0 and 1) to perform chroma suppression by reducing U and V as follow:

$U' = U * (F/256)$; and

$$V' = V * (F/256).$$

Again, U' and V' are the reduced chroma components of the current processing pixel. As such, the original chroma saturation of the current processing pixel is reduced to achieve chroma suppression on the current processing pixel.

In turn, transformation from YUV space back to RGB space is performed using reduced U' and V' as follow:

$$R = Y + ((351*V')/256;$$

$$G = Y - ((178*V' + 86*U')/256;$$

$$B = Y + ((443*U')/256.$$

As understood herein, chroma suppression in step 580 need not use the listed formula in the present embodiment. The above listed formula and their associated numerical values are for demonstrate purpose only. For example, in another embodiment of the invention, other numerical values can be used in place of the numerical values listed in step 580.

The foregoing descriptions of specific embodiments of the invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to explain the principles and the application of the invention, thereby enabling others skilled in the art to utilize the

invention in its various embodiments and modifications according to the particular purpose contemplated. The scope of the invention is intended to be defined by the claims appended hereto and their equivalents.